Monatomic Excitation Temperature in Theoretical Study of Discharge with Liquid Non-Metallic (Tap Water) Electrodes in Air at Atmospheric Pressure

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The discharge with liquid non-metallic electrodes under study is out of thermal equilibrium. From probe and micro-wave absorption measurements the electronic concentration has been evaluated. The spectral intensities of N_2 and Oxygen triplet have been measured locally. In this work, we propose to compare the results of calculation with the experimental results for two hypotheses on the monatomic excitation temperature. The first is when we assume the monatomic excitation temperature close to heavy particle translational temperature and the second is when we assume the monatomic excitation temperature close to the electronic translational temperature.

1. Introduction

The use of two liquid non-metallic electrodes in electric discharge offer unique properties that can be used in many available applications [1]. This kind of discharge has been constructed [2]. The metallic currents leads are inserted into the streams of tap water and covered by a ≈5 mm thick layer of tap water. The voltage is high between the leads (~ 3 kV) and the current density is low (~0.2-0.25 10^{-4} A·m^{-2}). It is a self-maintaining discharge, which burns steadily with DC supply between two streams of tap water in open air at atmospheric pressure in diffuse (volumetric) form (figure 1).

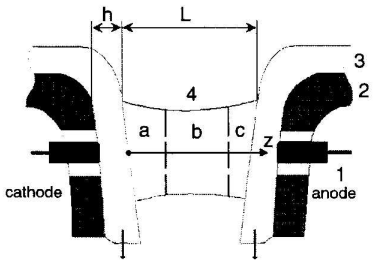

Figure 1.: Section view of the discharge with liquid non-metallic electrodes (schematically): 1 - metallic current leads, 2 - ceramics chutes, 3 - tap-water streams (electrodes), 4 - discharge plasma: a - near-cathode region, b - discharge column, c - near-anode region.

The experimental results show that we can separate the discharge in three zones : a near cathode region, a near anode region and a discharge column. The discharge column is not quite uniform. It some what narrows at the joint with the near-cathode region and expands toward the anode. The discharge column can be separate in two zones one near the cathode (Z≈2.5 mm) and the other near the anode (Z≈4.5 mm). These two zones have been investigated experimentally [2]. The main results useful for theoretical comparison are given in table 1.

	Cathode Zone	Anode Zone
Rotational Temperature	2100 ± 200 K	1500 ± 100 K
Vibrational Temperature	4200 ± 200 K	3800 ± 200 K
Electronic Concentration	1.5÷2 10^{18} m^{-3}	0.9÷1.2 10^{18} m^{-3}
N_2 Intensity (376÷380 nm)	4÷6 W/m^3	3÷4 W/m^3
O triplet Intensity (777 nm)	0.11÷0.14 W/m^3	0.02÷0.025 W/m^3

Table 1: Main Experimental Results

About the calculation of composition in plasma out of thermal equilibrium, many papers have been written [3]. We choose to make the calculation with the Gibbs free energy minimisation with two hypotheses on the temperatures (table 2). As a matter of fact, the rotational temperature is usually taken equal to the translational temperature of heavy species (T_{trh}) [4]. Since the vibration temperature is higher than the rotational temperature, we choose

that the excitation temperature of diatomic species T_{ex}^{diat} is equal to the translation temperature of electrons (T_{tre}). The relaxation value of monatomic excitation temperature is a debatable point [5, 6]. It depends on electronic concentration, excitation monatomic energy levels, excitation and de-excitation cross sections... So, one difficulty in our plasma discharge is to be sure to make the right hypothesis on excitation temperature of monatomic species T_{ex}^{at}. Consequently, we have made the two following hypotheses:

Hypothesis 1	*Hypothesis 2*
$\begin{cases} T_{tre} = T_{ex}^{diat} = T_{ex}^{at} = \theta T_{trh} \\ T_{vib} = 2.4 * T_{rot} \\ T_{rot} = T_{trh} \end{cases}$	$\begin{cases} T_{tre} = T_{ex}^{diat} = \theta T_{trh} \\ T_{vib} = 2.4 * T_{rot} \\ T_{rot} = T_{ex}^{at} = T_{trh} \end{cases}$

Table 2: Temperatures hypotheses.

2. Results

In figure 2, we present the electronic concentration for the two considered hypotheses and for three thermal non-equilibrium coefficients $\theta = \frac{T_{tre}}{T_{trh}}$.

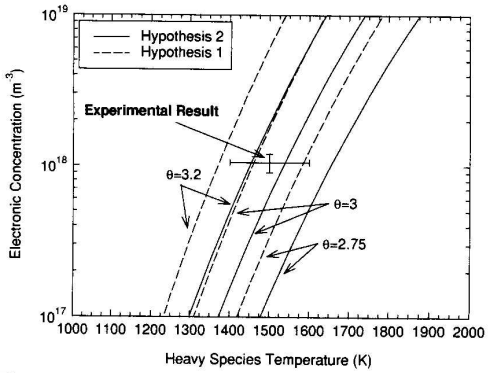

Figure 2: Anode Zone Electronic concentration for a plasma of 25% water vapour and 75% of air (molar percentage) at atmospheric pressure.

We remark that the electronic concentration is lower for the second hypothesis than for the first. So, the thermal non-equilibrium coefficient has to be higher to find the experimental value of electronic concentration.

In figure 3, the volumetric emission coefficient of oxygen triplet is plot for the considered thermal non-equilibrium coefficient and hypotheses. So, we remark that with the second hypothesis we are far from experimental value.

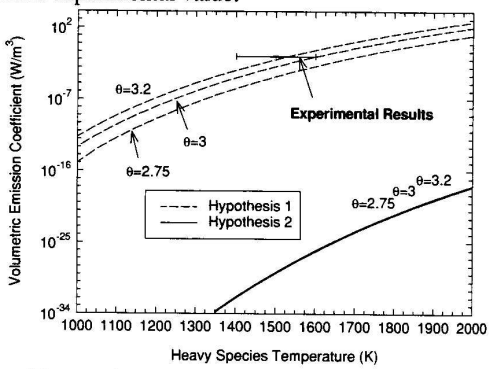

Figure 3: Anode Zone Volumetric Emission Coefficient of oxygen triplet.

3. Conclusion

>From the comparison of volumetric emission coefficient of oxygen triplet between the experimental results and theoretical calculation, the best hypothesis is when the monatomic excitation temperature is closed to the electronic translational temperature. The experimental results have been compared only with the triplet oxygen. So, it will be interesting to confirm this fact by adding metallic salt in water to contaminate the plasma discharge and then, from the spectral line of metallic species, evaluate the monatomic excitation temperature from several monatomic excitation energy levels.

4. References

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